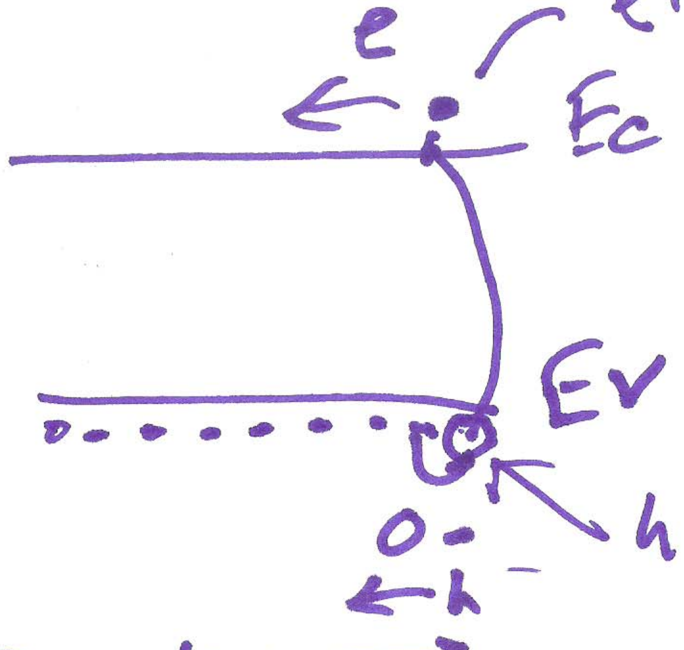
EE 421 / EGG 621

Lecture 4

Section 2.4

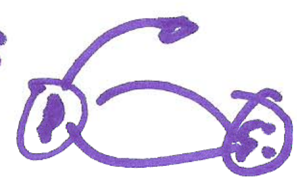
Si – 4 valence

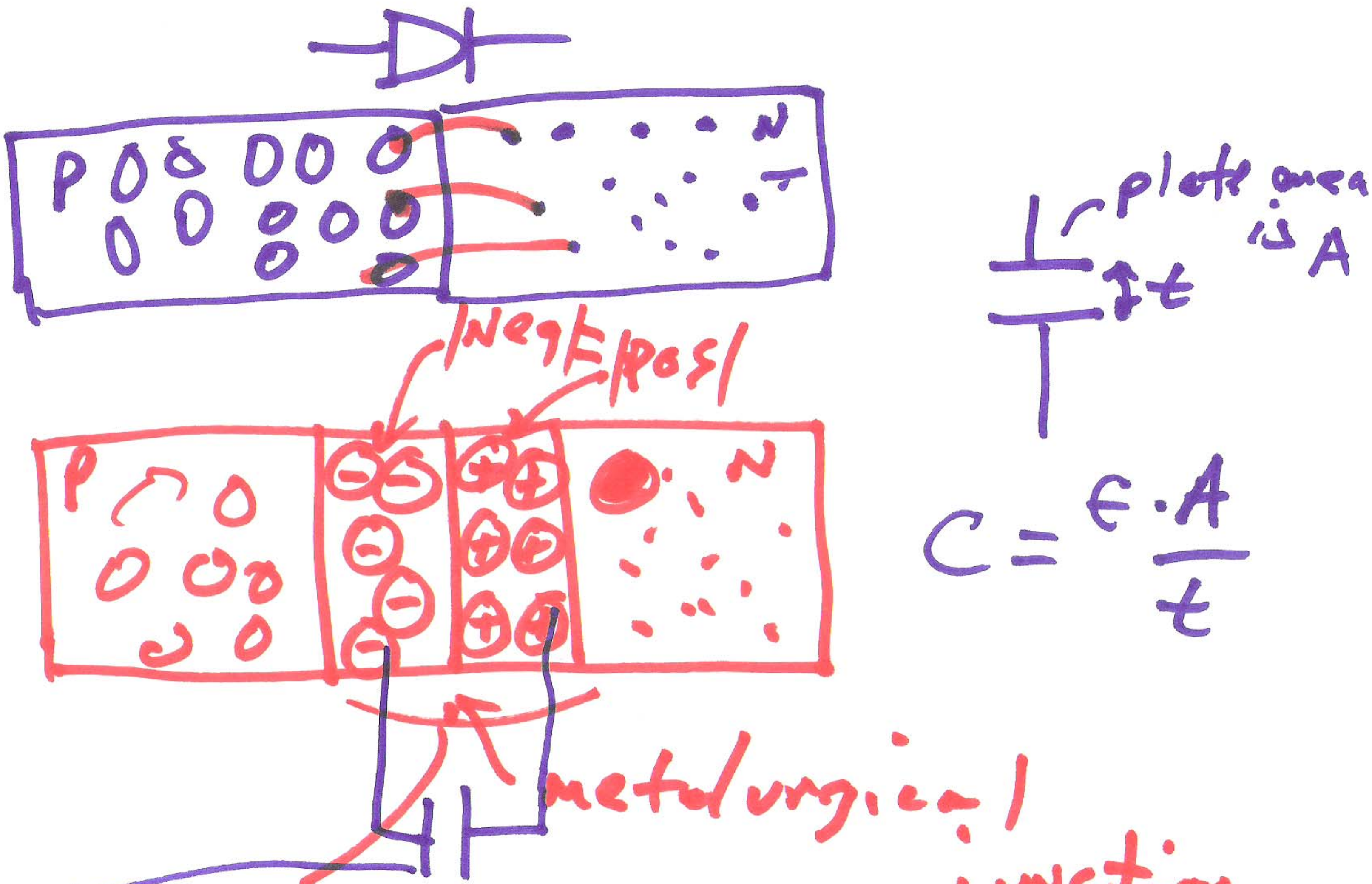


$J = |J_e| + |J_h|$

p-type doped
B → 3 valence electrons

N-type doped
P → 5 valence e

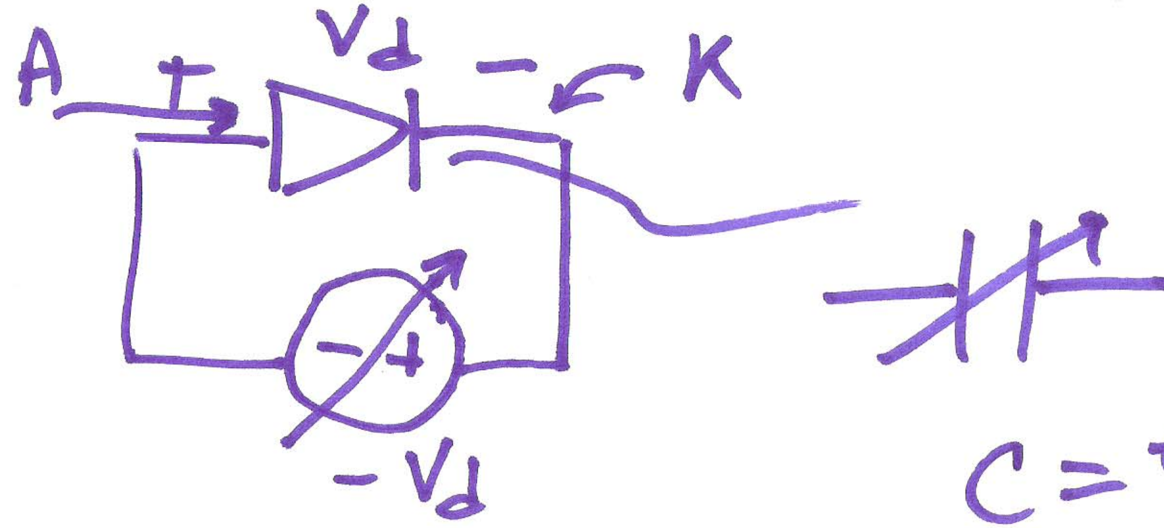




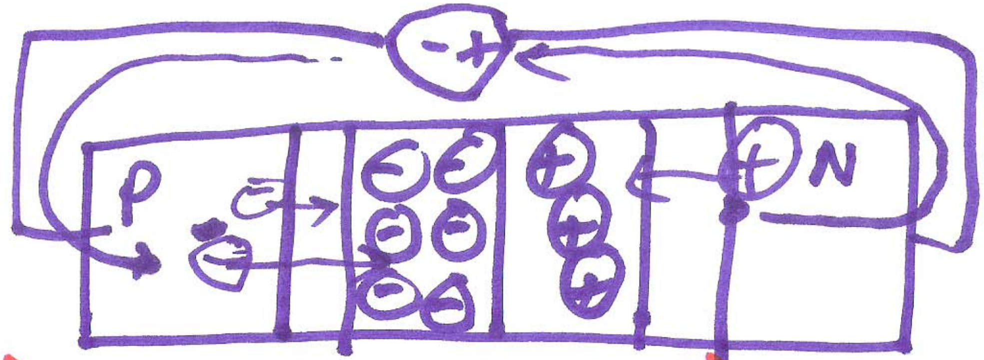
depletion CAP

depletion region

depleted of free carriers



$$C = \epsilon \frac{A}{t}$$

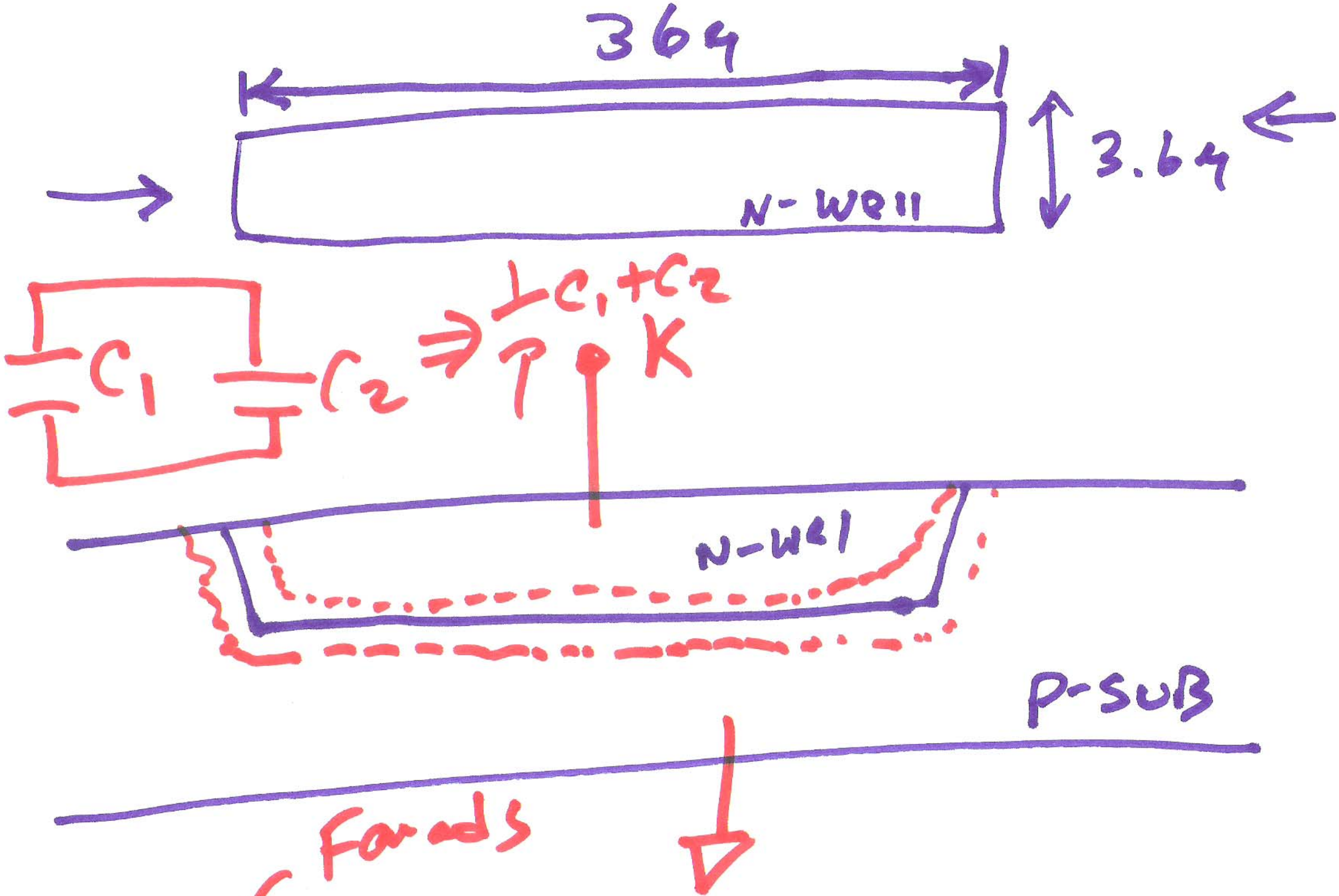


$$C_j(V_d) = \frac{C_{j0}}{\left(1 + \frac{|V_d|}{PB}\right)^{MJ}}$$

MJ – Grading coeff

PB – built-in potential

C_{j0} = zero-bias depletion C

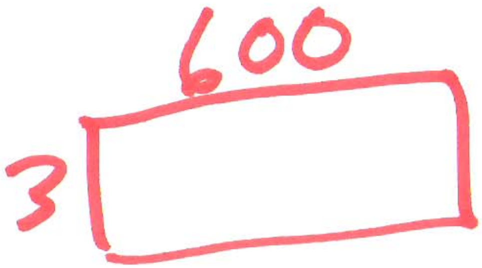


Farads

$$C_j = C_{bottom} + C_{sidewall}$$

$C_b \cdot Area_{bottom}$ (C_b: F/m²)

$C_{sw} \cdot Perimeter$ (C_{sw}: F/m)



$10\lambda \times 2{,}000\lambda$ $\quad \lambda = .3$

~~3.6μ~~ $\times$ ~~720μ~~ $\quad R_D = 800$

$3\mu \times 600\mu$

$R = \frac{600}{3} \times 800 = 16K$

$100\ aF/\mu m^2 = C_{job}$ of bottom

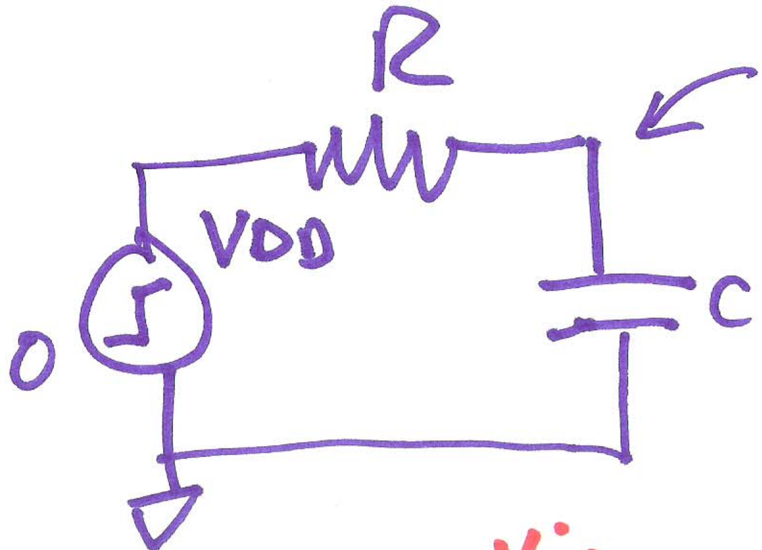
$50\ aF/\mu m = C_{josw}$ of sw

Est. total C_{jo}

$C_{jo} = C_{jsw} \cdot 1206\mu + C_{job} \cdot 1{,}800\mu^2$

$= \frac{50aF}{\mu} \cdot 1206 + \frac{100aF}{\mu^2} \cdot 1{,}800\mu^2$

5)



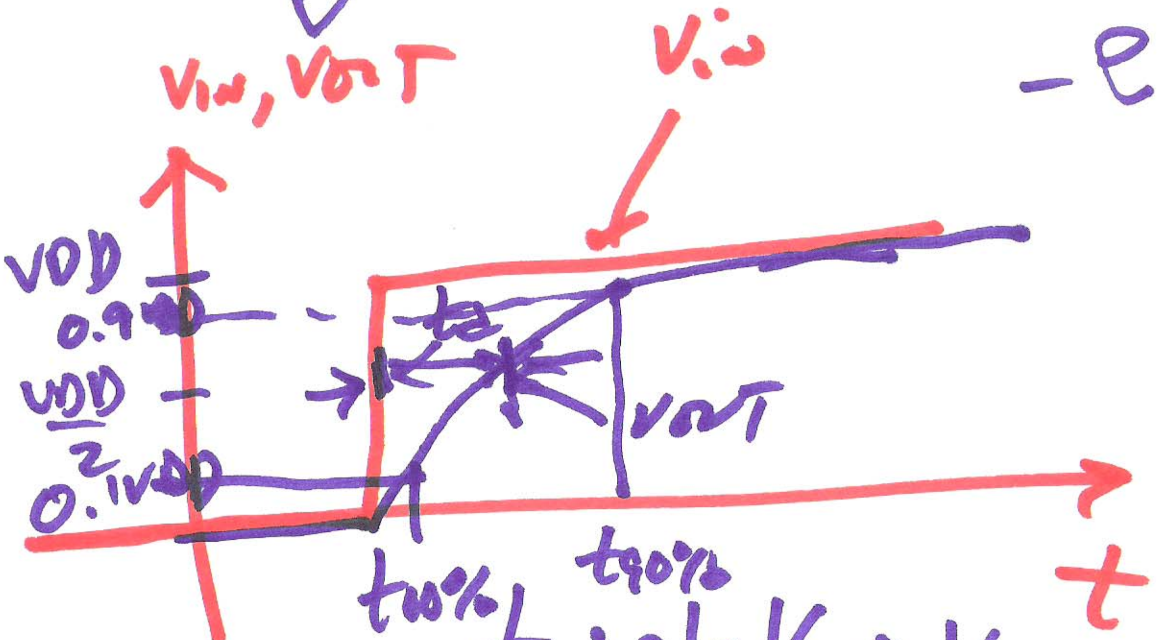
$$v_{OUT}(t) = VDD\left(1 - e^{-t/RC}\right)$$

$$\frac{VDD}{2} = VDD\left(1 - e^{-\frac{t_d}{RC}}\right)$$

$$-e^{-t_d/RC} = -\frac{1}{2}$$

$$t_d = RC\left(-\ln\frac{1}{2}\right)$$

$$\boxed{t_d = 0.7\,RC}$$



t delay → V_{OUT} = 50% VDD

$t_{90\%} - t_{10\%} =$ t_r = 0.1 VDD to 0.9 VDD

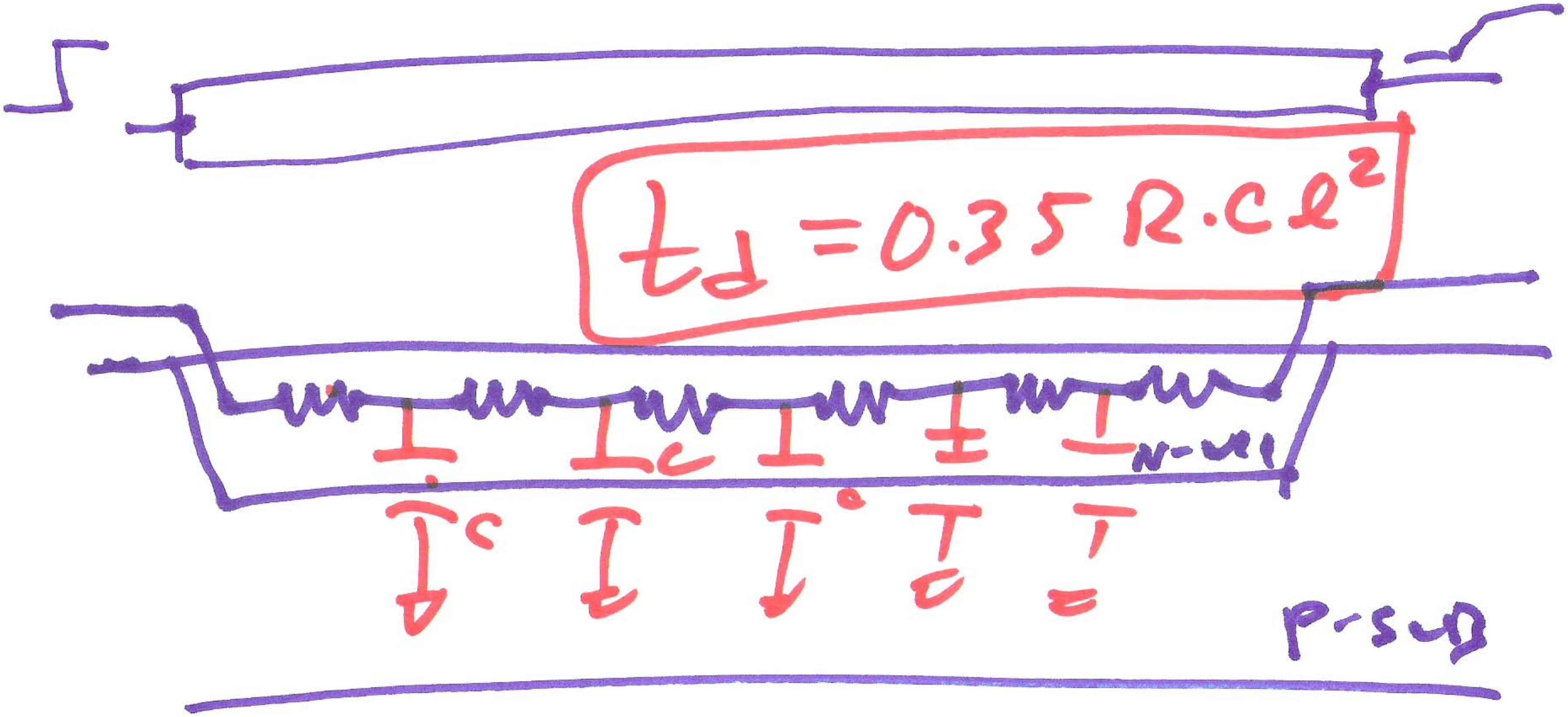
$$0.1V_{DD} = V_{DD}\left(1 - e^{-\frac{t_{10\%}}{RC}}\right)$$

$$0.9V_{DD} = V_{DD}\left(1 - e^{-\frac{t_{90\%}}{RC}}\right)$$

$$t_r = t_{90\%} - t_{10\%} = 2.2RC$$

$$\boxed{t_r = 2.2RC}$$

N-well Resistor



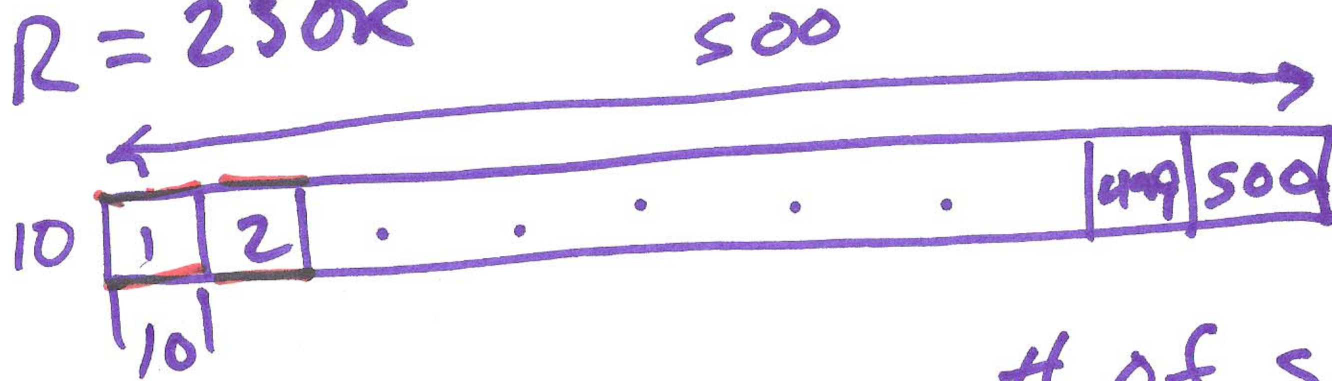
$$t_d = 0.35\,R\cdot C\ell^2$$

$$t_d = 0.7\cdot RC + 0.7\,2R\cdot C + 0.7\,3R\cdot C$$

$$t_d = 0.7RC(1+2+3+\dots\ell) + 7.4RC$$

$$t_d = 0.RC\,\frac{\ell(\ell+1)}{2} \simeq 0.7RC\,\frac{\ell^2}{2}$$

$R = 250K$



\# of squares

$$\frac{500}{10} = 50$$

$10 \times 10 \quad C = 5\,fF$

$$l = 50$$

$$R = 250K = R_\square \cdot \frac{10}{500}$$

$$t_d = r c\, l^2 \cdot .35$$

$$= 5K \cdot 5fF \cdot (50)^2 \cdot .35$$

$$= \underline{\underline{22\,ns}}$$

at room temp

the number of intrinsic carriers is called N_i

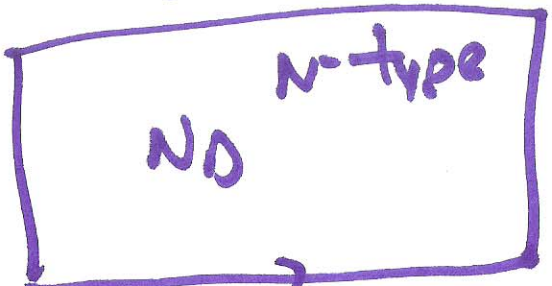
$N_i \approx 14.5 \times 10^9 \frac{\text{carriers}}{\text{cm}^3}$ @ 300K

under equilibrium

$$N_i^2 = N \cdot P$$

$$P \cdot N_D = N_i^2$$

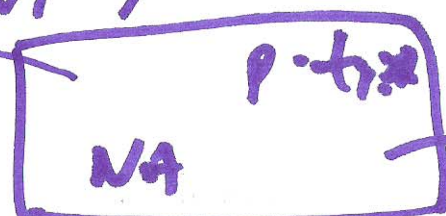
$$P = \left(\frac{N_D}{N_i^2}\right)^{-1}, \quad N = N_D$$



electron concentration, $N \approx N_D$

$$N = \left(\frac{N_A}{N_i^2}\right)^{-1}$$

$$P = N_A$$



hole concentration, $P \approx N_A$